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ABSTRACT

Students in three grade 7 classes, a grade 6 class and a split grade 5/6 class were provided with calculators for use in their mathematics classes for a period of eight weeks. For the posttest on problem solving the 116 students were randomly assigned to the group using calculators on the posttest or to the group using only paper and pencil. In a second section of the posttest the groups were reversed so that all students took a test in both modes, that is using calculators in one section and using paper and pencil only in the other. Pretest differences were non-significant. Out of eight comparisons on measures of correct answers to problems, three comparisons were statistically significant in favor of the calculator mode of problem solving. The other five differences were non-significant. On measures of problems attempted and methods correct all differences were non-significant except three, and each of these were in favor of the calculator mode. These results are consistent with previous studies. The calculator has no negative effects over short term periods and sometimes has positive effects. (Author)

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REPORT NO. 81:3

THE EFFECTS OF USING HAND CALCULATORS IN THE LEARNING OF
MATHEMATICS IN GRADES THREE TO EIGHT

Dr. Walter Szetela

SE 034 842

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CALCULATOR AND PAPER AND PENCIL METHODS ON
PROBLEM SOLVING TESTS IN GRADES FIVE TO SEVEN

ACKNOWLEDGEMENTS

This study was made possible through the efforts and cooperation of many people. Financial support was provided by the Educational Research Institute of British Columbia. Thirty calculators were loaned for the study through the efforts of Mr. Vincent Nicola of Texas Instruments, Inc. Jim Strilesky provided valuable advice about application to conduct the study in Richmond schools. Doug Super, coordinator of mathematics in Richmond schools was helpful in identifying teachers who would be interested in participating in the study. He also located additional calculators for use in the study. The persons whose efforts were most valuable were the teachers who taught their mathematics classes using calculators for the eight week period. These teachers took time to discuss the plans and procedures for the study. They engaged in discussions during visits to the schools by the investigator. They gave advice as well as receiving it. These teachers conducted themselves with professionalism, integrity, and expertise. Following are the names and schools of the teachers:

Grade 5/6 - Kidd School - Edith McDonald

Grade 6 - Kidd School - Doug May

Grade 7 - Kidd School - Roy Macdonald

Grade 7 - King School - Laurie Broadhurst

The principals and office personnel in each school were also helpful and cooperative in the study.

To all of these people I extend my grateful thanks and appreciation for helping to find more information which will guide teachers and school boards in implementing policies regarding calculators in schools.

Walter Szetela

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PROBLEM SOLVING TESTS IN GRADES FIVE TO SEVEN

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ABSTRACT

Students in three grade 7 classes, a grade 6 class and a split grade 5/6 class were provided with calculators for use in their mathematics classes for a period of eight weeks. For the posttest on problem solving the 116 students were randomly assigned to the group using calculators on the post test or to the group using only paper and pencil. In a second section of the posttest the groups were reversed so that all students took a test in both modes, that is using calculators in one section and using paper and pencil only in the other. Pretest differences were non-significant. Out of eight comparisons on measures of correct answers to problems, three comparisons were statistically significant in favor of the calculator mode of problem solving. The other five differences were non-significant. On measures of problems attempted and methods correct all differences were non-significant except three, and each of these were in favor of the calculator mode. These results are consistent with previous studies. The calculator has no negative effects over short term periods and sometimes has positive effects.

CALCULATOR AND PAPER AND PENCIL METHODS ON
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Support for this study was given through a research grant
from the Educational Research Institute of British Columbia.

Introduction

Unlike most calculator studies where an experimental group uses calculators over a period of time while a control group uses only paper and pencil, this study involved students all of whom utilized calculators during instruction. Also unlike most studies with calculators, the study was conducted to determine if the use of calculators on a posttest would produce results favorable for calculators. Roberts (1980) in his review of calculator studies asserts that most calculator studies try to show that use of calculators will not harm students' paper and pencil skills. He refers to this type of study as a "negative orientation." We take a positive view in this study with the hypothesis that students who use calculators on a problem solving test will perform better than students who use paper and pencil only. Previous studies by the investigator (1979,1980,1980) with elementary school students in which calculators were used on posttests, have produced significant results in favor of the calculator groups. In those studies there was a control group during the instructional period, and in each of those studies there was at least one paper and pencil posttest. In no case where only pencil and paper were used were there significant differences between calculator and control groups.

Because the treatment in the present study is focused only on the posttest, it may be argued that the students who are restricted to paper and pencil on the posttest are preordained to disadvantage when compared with students who are permitted to use calculators on the posttest. This argument does have some merit, but any disadvantage can be mitigated provided that the calculator is used as a supplementary tool during the period of instruction instead of being used exclusively. In this way, paper and pencil skills are certainly maintained even while calculator skills are being learned.

Procedure

Subjects for this study were from two schools in Richmond, British Columbia. There was a split grade 5-6 class, a grade 6 class, and a grade 7 class from Kidd Elementary School. There were two grade 7 classes from King Road School. No special topics for calculators were assigned. The participating teachers followed the normal course outline and used the regular school textbooks. Problem solving experiences occurred frequently but intermittently as they normally would in elementary grades. At the outset of the study there were 116 students distributed as follows:

Grade 5-6 (Kidd)	22
Grade 6 (Kidd)	19
Grade 7 (Kidd)	23
Grade 7 (King)	25
Grade 7 (King)	27

Students followed normal class routines during the eight weeks of instruction. At Kidd School a class set of calculators was shared by the three teachers who held their classes at different times. This resulted in a heavy drain on batteries for the calculators, but most calculators required only one battery replacement. At King Road School, one teacher taught both grade 7 classes with one calculator for every pair of students. Most calculators were basic 4-function calculators including some TI-10 models loaned by the Texas Instruments Company*. Calculators were used to solve problems which were applications of such topics as decimals, percents, ratios, applications of measurement, and operations with whole numbers. The investigator met with teachers about once each week.

Test Instruments

Prior to the experimental period all subjects were given a pretest of basic computational skills with whole number operations. The tests used were from those constructed by Robitaille, Sherrill, Kelleher, and Klassen (1979). These tests are used throughout British Columbia. The posttest consisted of a total of twenty problems. These problems were divided into two sections. For the first section of ten problems *Appreciation is expressed for Mr. Vincent Nicola of Texas Instruments, Inc., for arranging for the loan of calculators.

one group of students in each class was randomly assigned to take the test using the calculator. The other half of the students in each class used only pencil and paper for this section of the test. For the second section of ten problems, the situation was reversed. The students who had used calculators for the first section of problems used pencil and paper only for the second section. The students who used pencil and paper on the first section then used calculators on the second section of ten problems. Thus all students were at one time in the calculator group (C) and at another time in the non-calculator group (N). The problems were designed to cover a wide range of difficulty level. However, the numbers which were used in the problems were chosen to be reasonable so as not to prejudice the results in favor of the calculator groups. Following are typical examples from the tests.

GRade 5-6 and Grade 6

7. In a recent Grand Prix, the winning driver drove at an average of 240 kilometres per hour. He was driving for 3.4 hours. What was the length of the race ?
17. A tiger can run 1.25 kilometres per minute. A human can run only 0.75 kilometres per minute. How much farther can a tiger run in ten minutes than a human ?

Grade 7

8. A photograph of 50 spectators at a football game showed 30 men and 20 women. If there were 10 000 people at the game, about how many would be women ?
18. On his examinations Paul scored 83 in geography, 76 in math, 89 in language arts. Andrew scored 66 in geography, 86 in math, and 75 in language arts. Who had the higher total and how much higher ?

Data Analysis

The pretest scores indicated that there were no significant differences between the comparison groups. Thus it was appropriate to use analysis of variance to test for significance of mean differences between groups. Data were analyzed only for the students who had taken both the pre and posttest. Remarkably there was not a single case of attrition among the original 116 students.

Results

Pretest results are shown in Table 1. For purposes of identification, students who used calculators on the first section of the posttest are labeled as the initial calculator (IC) group. Students who used paper and pencil only on the first section of the posttest are labeled as the initial pencil and paper group (IPP) group.

Table 1

Pretest Mean Scores and Standard Deviations - Grades 5/6,6,7

Grade	<u>Initial Calculator Group</u>			<u>Initial Paper and Pencil Group</u>		
	N	Mean	SD	N	Mean	SD
5/6	10	37.80	1.85	12	37.25	2.60
6	10	38.90	2.13	9	37.00	2.69
7(Kidd)	11	30.55	7.03	12	32.33	4.58
7(King)	25	23.52	8.73	27	27.56	8.09

As noted earlier the pretest results produced no differences between groups which were significant statistically. However, it should be noted that in the Grade 7 group at King Road School, there was an absolute mean difference of about 4 in the pretest scores. In fact this difference did approach significance ($p = 0.09$).

The results of the first section of the posttest are given in Table 2. There were significant differences in favor of the groups using calculators in Grades 5/6 and Grade 6. Although the difference between groups in the King Road Grade 7 group was not significant when analysis of variance was used, a separate analysis of covariance which did take the pretest scores into account, showed that the group using calculators did have a statistically greater mean than the non-calculator group.

In order to determine the effect of calculator use on number of problems attempted and on number of correct methods used, whether or not the answers were correct, Table 2 also gives the mean number of problems attempted and methods correct in addition to the number of problems correctly solved including correct answers.

Table 2

Mean Scores on First Section of Problem Solving Test

CALCULATOR GROUP					PENCIL AND PAPER GROUP			
Grade	N	Problems Attempted	Method Correct	Answer Correct	N	Problems Attempted	Method Correct	Answer Correct
5/6	10	9.40	7.90	7.50*	12	9.17	7.17	5.17
6	10	8.90	7.20*	6.80*	9	8.22	3.44	2.89
7	11	9.64	5.55	5.18	12	9.00	5.92	4.83
7	25	8.84	5.32	4.84	27	8.59	5.44	4.59

*Indicates significantly greater mean for calculator groups.

For the second section of the problem solving test the groups switched treatments. Those who used calculators on the first section used pencil and paper only on the second section and vice versa. The mean scores for number of problems attempted, methods correct, and answers correct are given in Table 3.

Table 3

Mean Scores on Second Section of Problem Solving Test

CALCULATOR GROUP					PENCIL AND PAPER GROUP			
Grade	N	Problems Attempted	Method Correct	Answer Correct	N	Problems Attempted	Method Correct	Answer Correct
5/6	12	9.67	7.75	7.33	10	9.20	7.40	6.10
6	9	8.89	6.00	5.11	10	8.80	6.50	5.00
7	12	9.42	7.75	7.00	11	9.45	7.82	6.45
7	27	9.70*	8.41*	8.00*	25	9.04	7.00	5.68

*Indicates statistically significant margin for calculator groups.

As noted in Table 3 the only significant differences occurred with the larger Grade 7 groups. The differences were significant not only for problems correct but problems attempted and methods correct as well. The absolute difference in problems attempted was small, but

the standard deviations were also very low, a contributing factor in the determination of significance levels. Although only 5 out of 24 comparisons shown in Tables 2 and 3 produced significant differences, all in favor of calculator groups, it is interesting to note that the mean scores of calculator groups were higher in 19 out of the 24 comparisons.

Discussion

In this study in which all subjects used calculators for eight weeks, comparisons were made between subjects who used calculators on a final test of problem solving and subjects who used only paper and pencil. The test was divided into two sections with students randomly assigned to the calculator mode on the first section of the test. Students who were in the paper and pencil mode on the first section were assigned to the calculator mode on the second section of the test. The results of the study are consistent with previous studies with calculators by the investigator as well as with calculator studies in general. When students use calculators on posttests as well as during instruction, they perform at least as well as with paper and pencil and when there are differences in performance, the differences are in favor of the calculator testing mode. In this study 5 out of 24 comparisons were statistically significant in favor of the calculator mode, and 19 out of 24 comparisons of mean scores were in favor of the calculator mode even though only 5 of these comparisons were significantly different. When these results are combined with the parallel study simultaneously undertaken by the investigator with students in grades 3,5,7, and 8 the evidence is even stronger in favor of calculator use. In the parallel study the grade 7 and 8 calculator groups performed better than the paper and pencil groups in the problem solving test when calculators were used. Out of 29 comparisons the calculator groups had higher mean scores in 20 cases. In four of these comparisons the differences were statistically significant in favor of calculator groups. In total there were 39 out of 53 comparisons in which the mean scores of the calculator groups were higher, with 9 of these differences statistically significant.

The evidence from these studies does indicate that calculators

can help to improve mathematical performance especially in problem solving. The evidence is not dramatic if one is looking for enormous differences. However, the direction of superiority towards calculator groups in the large majority of cases as well as a number of significant differences, should dispell the fears that are sometimes expressed about calculator use. This study, the companion study, previous studies by the investigator, and studies in general provide not a shred of evidence that use of calculators has harmful effects, at least over short runs. More studies over long periods of time are needed as are studies in which curricula have been specially designed to fully exploit advantages provided by the tool that is so widely used in every day life.

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A STUDY OF THE EFFECTS OF USING CALCULATORS FOR PROBLEM
SOLVING IN GRADES THREE, FIVE, SEVEN, AND EIGHT

ACKNOWLEDGEMENTS

This study was made possible through the cooperation and efforts of many people. Financial support was provided by the Educational Research Institute of British Columbia. Doug Super, Mathematics Coordinator in Richmond Schools was helpful in identifying teachers with an interest in the study as well as in helping to locate calculators for use in the study. Jim Strilesky provided advice on application to conduct the study in Richmond schools. But the persons whose efforts were most valuable were the teachers who taught both the calculator and non-calculator groups. These teachers took time to discuss the plans and procedures with the investigator. They engaged in discussions and offered advice during conferences held regularly during the eight week period of instruction as well as before. These teachers conducted themselves with professionalism, integrity, and expertise. Following are the names and schools of the teachers:

Grade 3 - King Road School - Wendy Klassen

Grade 5 - Quilchena School - Allen Gasser

Grade 7 - Mitchell School - Sheila Borman and William Jack

Grade 8 - McRoberts School - Robert Campbell

The principals and office personnel in each school were also helpful and cooperative in the study. Finally, Mr. Vincent Nicola of Texas Instruments was helpful by providing the loan of thirty calculators. To all of these people I extend my grateful thanks and appreciation for helping to find more information which will help teachers and school boards to implement policies regarding calculators.

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A STUDY OF THE EFFECTS OF USING CALCULATORS FOR PROBLEM
SOLVING IN GRADES THREE, FIVE, SEVEN, AND EIGHT

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ABSTRACT

Students in each of two grade 3,5,7, and 8 classes were randomly assigned to calculator instruction (C) or non-calculator instruction (N) for a period of 8 to 12 weeks. At each grade level one teacher taught both C and N groups. Regular school materials and texts were used, supplemented by additional materials for C groups. Pretest mean differences were non-significant. On tests of basic computational skills and a test of problem solving in which all subjects used paper and pencil only, there were no significant differences. On a test of problem solving where calculators were used by the C groups, the grade 7 and 8 groups using calculators scored significantly higher than the paper and pencil groups. The results are consistent with previous studies by the investigator and calculator studies in general. Evidence indicates that calculators do not harm basic paper and pencil computational skills in short term studies, and calculators appear to be helpful in improving problem solving performance.

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Support for this study was given through a research grant from the Educational Research Institute of British Columbia.

In a state-of-the-art review of studies of calculators in education, Suydam (1980) reports that

Data from many studies still seeking an answer to the question, "Does use of calculators hurt achievement scores?", continue to support the fact that students who use calculators for instruction achieve at least as high or higher than students not using calculators, even though the calculator is not used on the test.

Suydam also states that such studies, where students use calculators during the instructional period, followed by paper and pencil achievement tests, comprise about two-thirds of all studies reported. Roberts (1980) asserts that when calculators are not used on posttests, "this reflects a philosophy that the real question is whether the use of calculators will harm students' performance when they are faced with calculation by paper and pencil methods." He regards this as a "negative orientation" and suggests that allowing the use of calculators on criterion tests is a more useful research strategy.

In the present study conducted at four grade levels, two posttests were given. On the first test all subjects used paper and pencil only on both skills tests and problem solving tests. On the second posttest, students in the calculator groups were allowed to use calculators while students in the control groups used paper and pencil. The entire second posttest was on problem solving. Thus the first posttest was given to determine if students in the calculator groups would maintain skills with pencil and paper calculation equal to the control groups, while the second posttest was given to determine

if use of the calculator on the posttest as well as during instruction would result in superior problem solving performance for the calculator groups.

Procedure

The study was conducted in four schools in Richmond, British Columbia. There were two classes with one grade level for each school. In each school one teacher taught two classes, one using calculators, the other using regular school materials. In three schools students from the two classes were randomly assigned to the Calculator (C) Group or to the Non-calculator (N) Group. In one school there were two intact grade eight classes taught by the same teacher. However, assignment to these two classes was made by the school computer without regard to ability level. The period of instruction for grades three, five, and seven was eight weeks while the grade eight classes participated in the study for twelve weeks. Topics of instruction for each grade are shown below with the number of students participating shown in parentheses:

- Grade 3 (50) - Whole number operations with multiplication and division and problem solving applications.
- Grade 5 (36) - Introduction to decimals, operations with decimals, problem solving applications.
- Grade 7 (49) - Decimals, ratios, percents, problem solving.
- Grade 8 (52) - Decimals, ratios, percents, problem solving.

Materials

Regular classroom materials including the school textbooks were used in all classes. In addition to calculators for the C groups, some special materials such as calculator activity books and calculator problem cards were used. The calculators came from a variety of sources including a Richmond secondary school, thirty calculators on loan from the Texas Instruments Company,* and twenty calculators acquired by the investigator from a grant in previous calculator research. There was one calculator for each two students. Although there was a variety of calculators, students had no difficulty using any of them. None of the calculators had long life batteries, but battery replacement was not a serious problem.

*Appreciation is expressed for Mr. Vincent Nicola of Texas Instruments, Inc., for donating for use of calculators.

Instruction

At each of the four grade levels in the study, one teacher performed the instruction for both the C and N groups. For the grade three and five levels, another teacher released a class for the mathematics period to enable the teacher participating in the instruction to have access to two classes of students available for random assignment to calculator or non-calculator groups. Two grade seven teachers participating in the study, divided instructional responsibilities equally among the C and N groups. In the two grade eight classes one teacher was regularly assigned to both classes. The normal topics of instruction were followed in each class. The investigator met with each teacher prior to the study in order to plan the activities and program of instruction. During the eight to twelve week period of instruction, discussions took place with the teachers, and some calculator materials were given to the teachers. No unusual problems developed either during the instructional period or during the testing.

Test Instruments

All subjects were pretested on numerical skills appropriate to the grade levels. The pretests used were developed by Robitaille, Sherrill, Klassen, and Kelleher for use in British Columbia schools.(1979). These tests are available for grades 3,4,7, and 8. The grade 5 test was constructed by using items from the grade 4 and grade 7 tests. Following the treatment period there were two posttests. The first test was on computational skills and on problem solving for each of the four grades, but the grade five groups also took a test on decimal concepts. All of these tests were performed by all subjects with paper and pencil only. In all cases there were 16 items on computational skills and 10 problems to be solved. There were 20 items on the decimal concepts test.

The second posttest consisted of 20 problems to be solved. On this test, students in the C group were allowed to use calculators. All posttests were constructed by the investigator who endeavored to match the test content with the topics which had been studied. The time allotment for the various tests was only slightly adjusted after consultation with the teachers who adjudged all tests to be valid with respect to their instructional content.

Data Analysis

Although students had been randomly assigned to treatment with the exception of the grade eight classes, the pretest scores were obtained in order to determine if any of the treatment groups were significantly different with respect to mathematics ability at the outset of the study. None of the differences between treatment groups were significant although the pretest scores of the grade five non-calculator group exceeded the scores of the calculator group by a margin which at first appeared might be significant. The relatively high standard deviations in the grade five groups coupled with the relatively small sample sizes in these groups contributed to the non-significance of a difference of about 2.7 in the pretest means.

Measures obtained from the posttests were used to perform analysis of variance to test the significance of differences between means. Single measures were taken for the test of basic computational skills and for the concepts test in grade five. For the two problem solving tests for each level, three measures were taken for each test. These measures were taken to help answer the following questions:

1. Do students who use calculators during instruction but paper and pencil on tests, perform as well in problem solving as students who use paper and pencil during instruction as well as on tests?
2. Do students who use calculators during tests as well as during instruction, perform better than students who use paper and pencil during instruction and also on tests of problem solving?

For each of these questions comparisons were made on criteria of 1) number of problems attempted; 2) number of correct methods of solution; 3) number of problems solved correctly.

Data were analyzed only for the students who took the pretest and both posttests. Of the 187 students who participated in the study, 180 were present for all three tests.

Results

The results of the pretests which had Hoyt estimates of reliability ranging from 0.81 to 0.90 are given in Table 1. Except for the grade five pretest scores as noted earlier, the treatment group means were very nearly equal.

Table 1
Pretest Mean Scores and Standard Deviations - Grades 3,5,7,8

Grade	Calculator Group (C)			Non-Calculator Group (N)		
	N	Mean	SD	N	Mean	SD
3	25	24.52	6.68	21	24.67	6.05
5	16	29.56	4.76	17	31.88	5.16
7	23	27.48	8.18	24	27.21	7.73
8	28	31.71	6.03	26	30.04	6.25

The results of the first posttest which included 16 items on computational skills and 10 problems are given in Tables 2 and 3. The Concepts subtest on decimals which was given only in grade five is also given in Table 2. These tests were written by all students using pencil and paper only.

Table 2
Mean Scores on Skills Tests and Grade Five Concepts Test

Grade	Calculator Group (C)		Non-Calculator Group (N)	
	Skills	Concepts	Skills	Concepts
3	13.76*		9.29	
5	8.31	8.06	10.06	10.12
7	11.83		11.04	
8	11.79		12.46	

*This mean significantly better than N Group mean at 0.01 level.

Table 3

Mean Scores on Problem Solving Test (Pencil and Paper Only)

<u>Grade</u>	<u>Calculator Group (C)</u>			<u>Non-Calculator Group (N)</u>		
	<u>Problems Attempted</u>	<u>Method Correct</u>	<u>Correct Answer</u>	<u>Problems Attempted</u>	<u>Method Correct</u>	<u>Correct Answer</u>
3	9.08	7.04	5.56	8.67	6.24	4.19
5	8.56	5.38	4.19	9.24	7.12	5.59
7	9.48	6.78	5.91	9.33	6.67	5.33
8	9.39	7.21	5.96	9.23	6.08	5.19

None of the differences on the problem solving test where all students used paper and pencil were significant. However, the higher scores of the grade three group which used calculators, were very nearly significant on the measure of correct answers ($p = 0.08$). At the same time the higher scores of the grade five group which did not use calculators were very nearly significant as well ($p = .07$).

The results of the second posttest which involved problem solving are given in Table 4. On this test students in the C Group were allowed to use calculators. There were 20 problems on this test.

Table 4

Mean Scores on Problem Solving Test With Calculators in C Group

<u>Grade</u>	<u>Calculator Group (C)</u>			<u>Non-Calculator Group (N)</u>		
	<u>Problems Attempted</u>	<u>Method Correct</u>	<u>Correct Answer</u>	<u>Problems Attempted</u>	<u>Method Correct</u>	<u>Correct Answer</u>
3	19.04	14.12	11.96	18.00	12.81	9.00
5	16.75	10.19	9.13	17.59	12.06	10.65
7	18.70*	14.61	13.57*	17.00	12.71	10.83
8	18.64	14.89	13.79*	18.50	13.92	11.50

*These means significantly better than N Group means at 0.05 level.

As indicated in Table 4, the C Groups were significantly better on a problem solving test when calculators were permitted on the posttest in grades 7 and 8. The C Group in Grade 7 also attempted significantly more problems. Although the Grade 3 Group using calculators appeared to have a substantial mean difference margin over the corresponding group not using calculators, the difference fell just short of significance ($p = 0.0571$).

Discussion

The results of this study give further evidence that the use of calculators in mathematics teaching does not result in a decrease of paper and pencil skills, at least over a period of a minimum of eight weeks. At the same time it appears that the calculator can be beneficial in improving problem solving performance when students are allowed to use calculators on tests as well as during instruction. This statement should be made with the understanding that this study did not produce many significant results, but the results which were significant did favor the calculator groups. When many comparisons are made, one expects to get significant differences by chance. However, a count of higher group means indicates that in 20 out of 29 comparisons, the C Group means were higher. All nine comparisons which favored the N Group were in Grade 5. We earlier noted that the N Grade 5 group had a higher pretest mean than the C Group even though the difference did not reach significance.

It should be noted that on the posttests one group was at some disadvantage. When the posttests were with paper and pencil, this would seem to weigh against the C Groups who had used calculators during their instruction. When the posttests allowed the C Groups to use calculators while the N Groups used pencil and paper, this would seem to weigh against the N Groups.

Considered in total, the results clearly encourage the use of calculators to promote problem solving performance. In this study calculators were used with regular school materials except for some additional materials designed to supplement the regular text materials. If calculators can be used to produce results at least as good and sometimes better than that which results from learning without calculators in a curriculum not designed for calculator use, one may feel optimistic about the results of using calculators when used in a curriculum designed to fully take advantage of calculators.

The results of this study, several previous studies of the investigator, and calculator studies in general, which demonstrate that the use of calculators promote mathematics learning, should serve to encourage school districts and teachers to utilize calculators in their mathematics instruction. However, it is apparent that utilization of calculators in schools is still sparse. Research results do not seem to have a serious impact on the planning of mathematics instruction. Perhaps school curricula are too impervious to change. Perhaps teachers lack the confidence to use new tools. Perhaps standardized tests exert more influence on curriculum than research results, and thus far standardized tests reflect a pencil and paper curriculum. It is also possible that the research on calculators, while favoring calculators, has not produced dramatic differences. There is much research yet to be done, but the type which would be most effective is the type most difficult to conduct. Such research would be focused on totally new curricular materials and sequencing which would precede the use of calculators, in contrast to most of the research where calculators are simply attached to curricula which were never designed for the use of a tool so remarkable as the calculator.

Epilog

A second study with calculators was conducted parallel with the present study. In this second study, all students used calculators during instruction. The treatment consisted solely of the use of calculators on a problem solving posttest in contrast with the use of pencil and paper on the posttest. The details of this parallel study are given in a separate paper.

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